

DESCRIPTION

SOLID OXIDE FUEL CELL AND SEPARATOR

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Technical Field

The present invention relates to a solid oxide fuel cell, more specifically to a separator in a planar solid oxide fuel cell in which the introduced gas is supplied to the whole area of a current collector to thereby equalize the imbalance in the electrode reaction, and the improvement of the electric power generation efficiency is achieved.

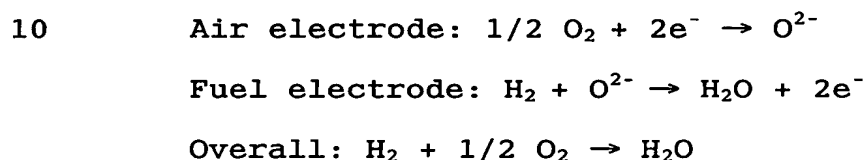
Background Art

The development of a solid oxide fuel cell, having a laminate structure in which a solid electrolyte layer made of an oxide ion conductor is sandwiched between an air electrode layer (oxidant electrode layer) and a fuel electrode layer, is progressing as a third-generation fuel cell for use in electric power generation. In a solid oxide fuel cell, oxygen (air) is supplied to the air electrode section and a fuel gas (H_2 , CO and the like) is supplied to the fuel electrode section. The air electrode and the fuel electrode are both made to be porous so that the gases can reach the interfaces in contact with the solid electrolyte layer.

The oxygen supplied to the air electrode section passes through the pores in the air electrode layer and reaches the neighborhood of the interface in contact with the solid electrolyte layer, and in that portion, the oxygen receives

electrons from the air electrode to be ionized into oxide ions (O^{2-}). The generated oxide ions move in the solid electrolyte layer by diffusion toward the fuel electrode. The oxide ions having reached the neighborhood of the interface in contact
5 with the fuel electrode react with the fuel gas in that portion to produce reaction products (H_2O , CO_2 and the like), and release electrons to the fuel electrode.

The electrode reaction when hydrogen is used as fuel is as follows:



Because the solid electrolyte layer is the medium for migration of the oxide ions and also functions as a partition
15 wall for preventing the direct contact of the fuel gas with air, the solid electrolyte layer has a dense structure capable of blocking gas permeation. It is required that the solid electrolyte layer has high oxide ion conductivity, and is chemically stable and strong against thermal shock under the
20 conditions involving the oxidative atmosphere in the air electrode section and the reductive atmosphere in the fuel electrode section; as a material which can meet such requirements, generally a stabilized zirconia (YSZ) that is added with yttria is used.

25 On the other hand, the air electrode (cathode) layer and fuel electrode (anode) layer need to be formed of materials having high electronic conductivity. Because the air electrode material is required to be chemically stable in the

oxidative atmosphere of high temperatures around 700°C, metals are unsuitable for the air electrode, and generally used are perovskite type oxide materials having electronic conductivity, specifically LaMnO_3 or LaCoO_3 , or the solid solutions in which part of the La component in these materials is replaced with Sr, Ca and the like. Moreover, the fuel electrode material is generally a metal such as Ni or Co, or a cermet such as Ni-YSZ or Co-YSZ.

The solid oxide fuel cell is classified into the high temperature operation type operated at high temperatures around 1000°C and the low temperature operation type operated at low temperatures around 700°C. A solid oxide fuel cell of low temperature operation type uses an electric power generation cell which is improved to work as a fuel cell even at low temperatures by lowering the resistance of the electrolyte, for example, through making the electrolyte made of an yttria stabilized zirconia (YSZ) be a thin film of the order of 10 μm in thickness.

A solid oxide fuel cell operable at high temperature uses for the separator, for example, a ceramic having electronic conductivity such as lanthanum chromite (LaCrO_3), while a solid oxide fuel cell of low temperature operation type can use for the separator a metallic material such as stainless steel.

Additionally, as the structure of the solid oxide fuel cell, there have been proposed three types, namely, a cylindrical type, a monolithic type and a flat plate type.

The stack of a solid oxide fuel cell has a structure in which electric power generation cells, current collectors and

separators are alternately laminated. A pair of separators sandwich an electric power generation cell from both sides of the cell in such a way one of the separators is in contact with the air electrode through the intermediary of an air electrode current collector while the other separator is in contact with the fuel electrode through the intermediary of a fuel electrode current collector. For the fuel electrode current collector, a spongy porous substance made of a Ni based alloy or the like can be used, while also for the air electrode current collector, a spongy porous substance made of a Ag based alloy or the like can be used. A spongy porous substance simultaneously displays current collection function, gas permeation function, uniform gas diffusion function, cushion function, thermal expansion difference absorption function and the like, and is accordingly suitable for a multifunction current collector.

The separators electrically connect between the electric power generation cells, and also have a function to supply the gas to the electric power generation cells; therefore, each separator has a fuel path through which the fuel gas is introduced from the peripheral side of the separator and is discharged from the separator surface facing the fuel electrode layer, and an oxidant path through which the oxidant gas is introduced from the peripheral side of the separator and is discharged from the separator surface facing the oxidant electrode layer.

<Problems to be Solved by the Invention>

<First Problem>

In the case of the solid oxide fuel cell of low temperature operation type, metal (stainless steel or the like) plates of the order of 5 to 10 mm in thickness are used for the separators, and there has hitherto been known a separator having a structure such that gas discharge openings to discharge the fuel gas and the oxidant gas introduced from the peripheral side of the separator into the current collector are provided in the central part of the separator.

Figure 8 is a sectional view of a relevant portion of a fuel cell stack illustrating an example of the above described separator. In Figure 8, reference numeral 3 denotes a fuel electrode layer, reference numeral 6 denotes a fuel electrode current collector, reference numeral 8 denotes a separator, reference numeral 11 denotes a fuel path, reference numeral 25 denotes a gas discharge opening, and the arrows indicate the gas permeation condition.

Here, it should be noted that such a conventional separator structure as described above is associated with the following problems.

More specifically, the structure is such that the fuel gas discharged from the central part of the separator 8 is supplied to the whole area of the fuel electrode layer 3 through the fuel electrode current collector 6 made of a porous cushioning material; however, in practice, there is a problem in that the fuel gas is consumed to a large extent by the electrode reaction in the neighborhood of the gas discharge

opening 25, and hence the gas concentration is decreased with increasing distance away from the gas discharge opening 25. Consequently, the electrode reaction is not uniformly conducted over the whole area of the electrode, a temperature
5 gradient is thereby generated in the electric power generation cell, the electric power generation cell is sometimes broken down by the thermal stress thus generated, and the resulting inefficient electric power generation leads to the degradation of the electric power generation properties (the electricity
10 production comes to be large in the central part of the electric power generation cell and small in the peripheral part of the same cell). This problem has been particularly conspicuous in the fuel electrode section.

Additionally, the use of thick metallic plates of 5 to
15 10 mm in thickness makes the weight of a single cell itself heavy, and accordingly, in the case of a solid oxide fuel cell constructed by longitudinally arranging cell stacks, there is a problem such that the electric power generation cells in the cell stacks located in the bottom portion tend to be
20 broken by the weight of the fuel cell. Consequently, as affairs stand, there remains a problem such that the cell configuration is inevitably constrained in such a way that the number of lamination is consistent with the tolerable weight of the fuel cell. Incidentally, in the case of a conventional structure,
25 the weight of a cell stack weighs about 1 kg, and the total weight of a cell module made by laminating a large number of this cell stack comes to be about 25 kg. Consequently, the structure supporting such a module is naturally complex.

<Second Problem>

As described above, in a conventional solid oxide fuel cell, each of the current collectors made of a porous cushioning material is arranged between an electrode layer and a separator, and the gas is distributed to be supplied to each of the electrode layers through the current collectors; however, there has been a problem such that in the conventional structure, the retaining time of the gas in a current collector is short, and consequently the fuel gas not engaging with the electrode reaction is discharged outside the electric power generation cell, so that the electric power generation efficiency is thereby degraded.

Additionally, in the conventional structure, the linear velocity of the gas in the peripheral part of the electric power generation cell comes to be slow; consequently there has also been a problem such that from the peripheral part of the electric power generation cell, air as oxidant is taken into the interior of the electric power generation cell, where the combustion reaction tends to take place, the combustion reaction completely consumes the fuel gas to be usable for the electrode reaction, and consequently the electric power generation efficiency is degraded.

Such an adverse phenomenon has remarkably taken place particularly in a fuel cell stack provided with the separators having a structure in which the fuel gas or the oxidant gas is supplied to the fuel cell electrode current collector or the oxidant electrode current collector from the central part of each separator.

Disclosure of the Invention

In view of the above described problems, a first object of the present invention is the provision of a planar solid oxide fuel cell in which the electric power generation efficiency is improved by uniformizing the electrode reaction in the current collectors and adverse effects such as breakdown accidents are prevented by making the separators light in weight, and the provision of the separator for use in the solid oxide fuel cell.

More specifically, the present invention according to claim 1 is a planar solid oxide fuel cell in which a fuel electrode layer and an oxidant electrode layer are arranged on both surfaces of a solid electrolyte layer, respectively; a fuel electrode current collector and an oxidant electrode current collector are arranged outside the fuel electrode layer and the oxidant electrode layer, respectively; respective separators are arranged outside the fuel electrode current collector and the oxidant electrode current collector; and a fuel gas and an oxidant gas are supplied from the respective separators to the fuel electrode layer and the oxidant electrode layer respectively, through the fuel electrode current collector and the oxidant electrode current collector, respectively, the fuel cell being characterized in that each of the separators includes a first gas discharge opening for discharging the introduced gas from the central part of the separator and a plurality of second gas discharge openings

for discharging the introduced gas along the peripheral part of the separator in a circular manner.

In the configuration described above, the gas is discharged from the central part of each separator and is discharged in a circular manner from the peripheral part of each separator; accordingly, the gas can be sufficiently supplied to and distributed over the whole areas of the current collectors. Consequently, the electrode reactions are made to be performed uniformly all over the whole areas of the electrodes; thus an efficient electric power generation can be carried out in which the difference in electricity production between the central parts and the peripheral parts is eliminated.

Additionally, the present invention according to claim 2 is characterized in that in the planar solid oxide fuel cell according to claim 1, the each separator is made up by laminating a plurality of thin metal plates at least including a thin metal plate provided with the first gas discharge opening and the second gas discharge openings and a thin metal plate with a worked indented surface.

According to the above described configuration, the separators themselves can be made light in weight, the concavities and convexities of the thin metal plates form the gas flow paths and hence the introduced gas is diffused uniformly over the whole areas of the separators, so that ensured is the gas supply to the first gas discharge openings as a matter of course and also to the second gas discharge openings formed in the peripheral parts in a circular manner.

Additionally, the present invention according to claim 3 is a planar solid oxide fuel cell according to claim 2, characterized in that the thin metal plate provided with the first gas discharge opening and the second gas discharge opening is arranged at least on the side of each of the fuel electrode current collectors.

The nonuniformity of the electrode reaction in the current collectors is conspicuous around the portions where the supplied gas enters. This is ascribable to the fact that in contrast to air (the oxidant gas), the fuel gas cannot be supplied in large amount, so that the supply amount is restricted. Accordingly, in the present configuration, such gas discharge structure as described above is applied at least to the separator portions in contact with the fuel electrode current collectors, so that the nonuniformity of the electrode reaction in the fuel electrode layers is reduced.

Additionally, the present invention according to claim 4 is a separator for use in a solid oxide fuel cell which is contacted with each current collector arranged outside each electrode to form a gas passage for supplying a gas to the electrode, characterized in that the separator includes a first gas discharge opening for discharging an introduced gas from the central part thereof and a plurality of second gas discharge openings for discharging the gas along the peripheral part thereof in a circular manner.

Additionally, the present invention according to claim 5 is the separator for use in a solid oxide fuel cell according to claim 4, characterized in that the separator is made up

by laminating a plurality of thin metal plates including at least the thin metal plate provided with the first gas discharge opening and the second gas discharge opening and a thin metal plate having a worked indented surface.

5 Additionally, the present invention according to claim 6 is the separator for use in a solid oxide fuel cell according to claim 5, characterized in that the thin metal plate provided with the first gas discharge opening and the second gas discharge opening is arranged at least on the side of the fuel
10 electrode current collector.

 Furthermore, in view of the above described problems involved in the conventional techniques, another object of the present invention is the provision of a solid oxide fuel cell in which the electric power generation efficiency is
15 improved by increasing the utilization ratios of the fuel gas and the oxidant gas in the current collectors, and the provision of the separator for use in the solid oxide fuel cell.

 More specifically, the invention according to claim 7 is a solid oxide fuel cell in which a fuel electrode layer and an oxidant electrode layer are arranged on both surfaces
20 of a solid electrolyte layer, respectively; a fuel electrode current collector and an oxidant electrode current collector, both collectors being formed of a porous substance, are arranged outside the fuel electrode layer and the oxidant
25 electrode layer, respectively; respective separators are arranged outside the fuel electrode current collector and the oxidant electrode current collector; and a fuel gas and an oxidant gas are supplied from the respective separators to

the fuel electrode layer and the oxidant electrode layer, respectively, respectively through the fuel electrode current collector and the oxidant electrode current collector, respectively; the fuel cell being characterized in that indents
5 are formed on the surface of each of the separators, which surface is in contact with each of the current collectors, to increase the dwell volume of the gas in the current collectors.

In the above described configuration, the current
10 collectors made of a spongy porous substance each are expanded in conformity with the depression of the associated separator, and hence the volumes of the separators are increased, so that the retaining time of the gas is elongated (the gas permeation rate is made slower) if the supplied amount of the gas is constant.
15 In this way, the reaction between the gases and the electrode layers comes to be conducted satisfactorily, and the electric power generation efficiency is thereby improved.

Additionally, the invention according to claim 8 is a solid oxide fuel cell in which a fuel electrode layer and an
20 oxidant electrode layer are arranged on both surfaces of a solid electrolyte layer, respectively; a fuel electrode current collector and an oxidant electrode current collector, both collectors being formed of a porous substance, are arranged outside the fuel electrode layer and the oxidant
25 electrode layer, respectively; respective separators are arranged outside the fuel electrode current collector and the oxidant electrode current collector; and a fuel gas and an oxidant gas are supplied from the respective separators to

the fuel electrode layer and the oxidant electrode layer, respectively through the fuel electrode current collector and the oxidant electrode current collector, respectively; the fuel cell being characterized in that the peripheral part of
5 the surface of each of the separators, which surface is in contact with each of the current collectors, is protruded expandably to increase the linear velocities of the gases in the peripheral parts of the current collectors.

The increase of the linear velocity of the gas being
10 discharged in the peripheral parts prevents the air entrained from the peripheral parts, and in particular, in the peripheral parts of the fuel electrode layers, can maintain the fuel gas concentration in an elevated concentration condition, and the electric power generation performance is thereby improved.

15 Additionally, the invention according to claim 9 is a solid oxide fuel cell in which a fuel electrode layer and an oxidant electrode layer are arranged on both surfaces of a solid electrolyte layer, respectively; a fuel electrode current collector and an oxidant electrode current collector,
20 both collectors being formed of a porous substance, are arranged outside the fuel electrode layer and the oxidant electrode layer, respectively; respective separators are arranged outside the fuel electrode current collector and the oxidant electrode current collector; and a fuel gas and an
25 oxidant gas are supplied from the respective separators to the fuel electrode layer and the oxidant electrode layer, respectively, through the fuel electrode current collector and the oxidant electrode current collector, respectively;

the fuel cell being characterized in that indents are provided on the surface of each of the separators, which surface is in contact with each of the current collectors, and the peripheral part of the separator is protruded expandably.

5 In the above described configuration, the gas permeation rate in the interior of the current collectors is made slow and the electrode reactions are made satisfactory, and the linear velocity of the gas in the peripheral parts is made fast, and the entraining of the air from the peripheral parts
10 can thereby be prevented. Consequently, the electric power generation performance can be improved.

 Additionally, the present invention according to claim
10 is the solid oxide fuel cell according to any one of claims 7 to 9, characterized in that the surface shape of the separators
15 is formed at least on the surfaces in contact with the current collectors.

 The phenomenon of the incomplete reaction of the gas in the interior of the current collectors takes place on the portions where the supplied fuel gas enters. This is
20 ascribable to the fact that in contrast to air (the oxidant gas), the fuel gas cannot be supplied in large amount, so that the supply amount is restricted. Accordingly, in the present configuration, the depressions and the protruded portions are provided at least on the surface, in contact with one of the
25 fuel electrode current collectors, of each of the separator, and the phenomenon of the incomplete reaction of the gas and the phenomenon of the entraining of the air in the fuel electrode current collector are thereby remedied.

Additionally, the invention according to claim 11 is the solid oxide fuel cell according to any one of claims 7 to 10, characterized in that the fuel cell includes a structure in which the fuel gas and the oxidant gas are supplied from the central parts of the separators, respectively, to the fuel electrode layer and the oxidant electrode layer, respectively, through the fuel electrode current collector and the oxidant electrode current collector, respectively.

Additionally, the invention according to claim 12 is a separator for use in a solid oxide fuel cell which is in contact with one of the current collectors arranged outside the respective electrodes to form a gas passage for supplying a gas to one of the electrode sections, characterized in that indents are provided on the surface of the separator, which surface is in contact with one of the current collectors, to increase the dwell volume of the gas in the current collectors.

Additionally, the invention according to claim 13 is a separator for use in a solid oxide fuel cell which is contacted with each current collector arranged outside the each electrode to form a gas passage for supplying a gas to each electrode section, characterized in that the peripheral part of the surface of the separator, which surface is in contact with the current collector, is protruded expandably to increase the linear velocity of the gas in the peripheral part of the current collector.

Additionally, the invention according to claim 14 is a separator for use in a solid oxide fuel cell which is contacted with each current collector arranged outside each electrode

to form a gas passage for supplying a gas to each electrode section, characterized in that indents are provided on the surface of the separator, which surface is in contact with the current collector, and the peripheral part of the surface
5 concerned is protruded expandably.

Additionally, the invention according to claim 15 is the separator according to any one of claims 12 to 14, characterized in that the surface shape of the separator is formed at least on the surface in contact with one of the fuel electrode current
10 collectors.

Brief Description of the Drawings

Figure 1 is an exploded oblique perspective view illustrating the configuration of a relevant portion of a
15 planar solid oxide fuel cell involved in the present invention;

Figure 2a and Figure 2b illustrate the structure of a separator on the side of a fuel electrode involved in the present invention; Figure 2a being a related plan view and Figure 2b being a related sectional view;

20 Figure 3 is a sectional view of a relevant portion of a fuel cell stack involved in the present invention;

Figure 4 is a sectional view of a relevant portion of a fuel cell stack illustrating the shape of the separator according to a second embodiment of the present invention;

25 Figure 5a to Figure 5d are sectional views illustrating the shapes of separators different from the shape shown in Figure 1;

Figure 6 is an exploded sectional view of a solid oxide fuel cell;

Figure 7 is an exploded perspective view of a relevant portion of the solid oxide fuel cell; and

5 Figure 8 is a sectional view of a relevant portion of a conventional fuel cell stack.

Best Mode for Carrying Out the Invention

Description will be made below on the embodiments of the
10 present invention with reference to the accompanying drawings. Incidentally, in the following description, for the simplification of description, the same reference symbols are used for the portions common to the conventional portions.

<First Embodiment>

15 Description will be made below on the first embodiment of the present invention with reference to Figure 1, Figure 2 to Figure 2b, and Figure 3; in the first place, on the basis of Figure 1, description will be made on the configuration of a solid oxide fuel cell involved in the present embodiment.

20 In Figure 1, reference numeral 1 denotes a fuel cell stack, which has a structure in which an electric power generation cell 5 in which a fuel electrode layer 3 and an air electrode layer (oxidant electrode layer) 4 are arranged respectively on both surfaces of a solid electrolyte layer 2, a fuel electrode
25 current collector 6 arranged outside the fuel electrode layer 3, an air electrode current collector (oxidant electrode current collector) 7 arranged outside the air electrode layer 4, and separators 8 arranged respectively outside the current

collectors 6 and 7 are laminated in this order. The present embodiment is suitably applicable to a sealless structure in which no gas seal is present along the rim of a fuel electrode current collector.

5 Here, the solid electrolyte layer 2 is formed of a stabilized zirconia (YSZ) that is added with yttria and the like, the fuel electrode layer 3 is formed of a metal such as Ni or Co, or a cermet such as Ni-YSZ or Co-YSZ, the air electrode layer 4 is formed of LaMnO_3 , LaCoO_3 or the like,
10 the fuel electrode current collector 6 is formed of a spongy porous sintered metal plate made of a Ni based alloy or the like, and the air electrode current collector 7 is formed of a spongy porous sintered metal plate made of a Ag based alloy or the like.

15 The separators 8 have a function to connect electrically between the electric power generation cells 5 similarly to the conventional separators, and also have a function to supply a gas to the electric power generation cells 5; however, the structure of the separators is different from the structure
20 of the conventional separators shown in Figure 8.

More specifically, the conventional separator is fabricated of a thick, single metal plate, whereas as shown in Figure 2a and Figure 2b, the separator 8 of the present embodiment has a three layer structure which is formed by
25 successively laminating a metal upper plate 21 provided with a plurality of gas discharge openings, an intermediate plate 22 processed to have a surface with alternate convexities and

concavities, and a flat lower plate 23. For all these plates, thin metal plates made of stainless steel or the like are used.

In the upper plate 21, a first fuel gas discharge opening 25 is formed in the central part thereof, and a plurality of second fuel gas discharge openings 24 are formed in a circularly aligned manner; the fuel gas introduced from the rim face of the separator 8 is discharged, through a fuel gas passage 11, from these gas discharge openings 24 and 25, and supplied to the fuel electrode current collector 6 facing the separator 8.

For the intermediate plate 22, there is used a sheet metal material processed so as to have a surface with alternate convexities and concavities for the purpose of ensuring the strength and the thickness as a separator; this plate is combined with the upper plate 21 and the lower plate 23 to form a hollow separator 8 as shown in Figure 2b. The hollow portions formed by these convexities and concavities function as the gas flow path making the fuel gas diffuse easily, and simultaneously the weight saving of the separator 8 can be actualized.

Incidentally, the worked indented surface can be formed by applying the plastic working to this sheet metal; in contrast to the rectangular shape shown in the figure, an corrugated shape (corrugated plate) may also be used. Additionally, a plate material provided with worked indented surface patterns by applying the embossing processing may also be used.

The lower plate 23 forms a partition wall between the fuel electrode section and the air electrode section. The

above described combination of the upper plate 21 and the intermediate plate 23 constitutes a separator structure on the fuel electrode side; in practice, the separator portion on the air electrode side is formed with the intervening lower plate 23, but in the figure concerned, the relevant portion
5 is omitted.

Incidentally, the separators 8 (8A, 8B) at both ends of the fuel cell stack 1 shown in Figure 1 have respectively either one of the above described separator structures on the fuel
10 electrode side and the air electrode side.

In the above described configuration of the planar solid oxide fuel cell, the fuel gas discharged from the central part and the peripheral part of the separator 8 can be spread over the whole area of the fuel electrode layer 3 with a satisfactory
15 distribution through the fuel electrode current collector 6; accordingly, the gas reaction can be carried out efficiently over the whole area of the electrode layer.

More specifically, a conventional type separator, provided with the gas discharge opening 25 merely in the central
20 part of the separator 8 shown in Figure 8, has a structure such that the gas can be hardly spread to the peripheral part, and accordingly, the electrode reaction is not spatially uniform, so that there have been caused problems including the breakdown of the electric power generation cell and the
25 degradation of the electric power generation efficiency due to the thermal stress; however, according to the separator structure of the present embodiment, as shown in Figure 3, the fuel gas introduced from the peripheral face of the

separator through the fuel path 11 is made to diffuse over the whole area of the separator by taking advantage of the hollow portions (convexities and concavities) of the separator 8 as the gas passage, the fuel gas is discharged from the first
5 fuel gas discharge opening 25 in the central part and the a plurality of second fuel gas discharge openings 24 in the peripheral part, and the fuel gas can be spread over the whole area of the fuel electrode layer 3 with a satisfactory distribution through the fuel electrode current collector 6
10 facing the separator. Consequently, the electrode reaction comes to be carried out uniformly over the whole electrode areas, and hence the electric power generation can be carried out efficiently with a vanishing difference in electricity production between the central part and the peripheral part.

15 Moreover, the separator 8 of the present embodiment is made to have a laminate structure with a hollow interior, and hence the weight of the separator itself can be drastically reduced as compared to the conventional type separator. Such a structure is extremely effective in a fuel cell module having
20 a structure in which a large number of cell stacks are longitudinally laminated, in view of the fact that the burden loaded on the electric power generation cells located in the lower positions is reduced; consequently, the supporting frame for the fuel cell module can be simplified, and the constraint
25 imposed on the number of lamination in the cell stack can be alleviated. Thus, an electric power generation of high electromotive force can be actualized.

As described above, as for the present embodiment, description has been made on the structure of the separator part in contact with the fuel electrode current collector 6, and a similar structure can be applied to the separator part in contact with the air electrode current collector 7. Additionally, some simple discharge structure other than those described above (for example, as shown in Figure 7, a gas discharge structure restricted to the central part) can be adopted. The nonuniformity of the electrode reaction in the interior of the current collectors is conspicuous around the portions where the supplied fuel gas enters, and accordingly, it is important to apply the structure of the present embodiment at least to the separator part facing the fuel electrode current collector 6.

Additionally, in the present embodiment, the separator 8 has a three layer structure formed of three thin metal plates; however, the separator structure is not restricted to this structure, and may take a two layer structure in which the lower plate 23 is omitted. In this way, a further weight saving of the separator 8 can be expected.

Additionally, in the present embodiment, there is presented a solid oxide fuel cell in which a stabilized zirconia (YSZ) that is added with yttria is used for the electrolyte in the electric power generation cell; however, the present invention can be applied to other solid oxide fuel cells such as those solid oxide fuel cells in which a ceria based electrolyte and a gallate based electrolyte are used.

<Second Embodiment>

Now, description will be made below on the second embodiment of the present invention. Figure 4 shows a sectional view of a relevant portion of a fuel cell stack illustrating the shape of the separator, Figure 5a to Figure 5d show the sectional views of the relevant portions illustrating the other examples of separators, Figure 6 shows an exploded sectional view of a solid oxide fuel cell, and Figure 7 shows an exploded oblique perspective view of the relevant portion of the same solid oxide fuel cell in the present embodiment.

In the first place, on the basis of Figure 6 and Figure 7, description will be made below on the configuration of the solid oxide fuel cell involved in the present embodiment.

In Figure 6, reference numeral 1 denotes a fuel cell stack, which has a structure in which an electric power generation cell 5 in which a fuel electrode layer 3 and an air electrode layer (oxidant electrode layer) 4 are arranged respectively on both surfaces of a solid electrolyte layer 2, a fuel electrode current collector 6 arranged outside the fuel electrode layer 3, an air electrode current collector (oxidant electrode current collector) 7 arranged outside the air electrode layer 4, and separators 8 arranged respectively outside the current collectors 6 and 7 are laminated in this order.

The solid electrolyte layer 2 is formed of a stabilized zirconia (YSZ) that is added with yttria and the like, the fuel electrode layer 3 is formed of a metal such as Ni or Co, or a cermet such as Ni-YSZ or Co-YSZ, the air electrode layer 4 is formed of LaMnO_3 , LaCoO_3 or the like, the fuel electrode

current collector 6 is formed of a spongy porous sintered metal plate made of a Ni based alloy or the like, the air electrode current collector 7 is formed of a spongy porous sintered metal plate made of a Ag based alloy or the like, and the separators
5 8 are formed of a stainless steel or the like.

Here, the porous metal plates forming the current collectors 6 and 7 are the plates having been fabricated through the following steps. The order of the steps is as follows: a step for preparing a slurry → a step for molding → a step
10 for foaming → a step for drying → a step for degreasing → a step for sintering.

In the first place, in the step for preparing a slurry, a metal powder, an organic solvent (n-hexane or the like), a surfactant (sodium dodecylbenzenesulfonate or the like),
15 a water soluble resin binder (hydroxypropylmethyl cellulose or the like), a plasticizer (glycerin or the like) and water are mixed together, and thus a foaming slurry is prepared. In the step for molding, by means of the doctor blade method, the slurry is molded in a thin plate shape on a carrier sheet,
20 and thus a green sheet is obtained. Then, in the step for foaming, this green sheet is foamed into a spongy condition in a high temperature and high humidity environment with the aid of the vapor pressure of the volatile organic solvent and the foaming property of the surfactant; subsequently, a porous
25 metal plate is obtained through the step for drying, the step for degreasing and the step for sintering.

In this case, in the step for foaming, the bubbles generated in the interior of the green sheet grow with nearly

spherical shapes as a result of receiving nearly equivalent pressures along all the directions. When a bubble diffuses to approach the interface to the atmosphere, the bubble grows toward the thin part of the slurry interposed between the bubble
5 and the atmosphere, and eventually the bubble is broken and the gas inside the bubble diffuses into the atmosphere through the formed small holes. Accordingly, there is obtained a porous metal plate provided with continuous pores having openings on the surface. The current collectors 6 and 7 each
10 are formed by cutting a thus fabricated porous metal plate having a three dimensional skeleton structure into a circular form.

On the other hand, as shown in Figure 6 and Figure 7, the separators 8 electrically connect between the electric
15 power generation cells 5, and also have a function to supply the gas to the electric power generation cells 5; therefore, each separator has a fuel path 11 through which the fuel gas is introduced from the peripheral side of the separator 8 and is discharged from the approximately central part of the
20 surface of the separator 8 facing the fuel electrode current collector 6, and an oxidant path 12 through which the oxidant gas is introduced from the peripheral side of the separator 8 and is discharged from the separator surface facing the air electrode current collector 7. Here, it should be noted that
25 the separators 8 (8A, 8B) at both ends of the stack have respectively either one of the paths 11 and 12.

Additionally, the separator 8 of the present embodiment is different from a flat shaped conventional type shown in

Figure 8, the surface of the separator 8 in contact with the fuel electrode current collector 6 is made to be bowl shaped, as shown in Figure 4, by providing a depression 8a with a deepened central part, and consequently the situation is such that the peripheral part 8b is raised. As has already been described, the material for the fuel electrode current collector 6 itself is formed of a spongy foam, and hence, at the time of lamination, the foam is arranged in a condition such that the foam is in close contact with the depression shape of the separator 8. Therefore, as far as the separator 8 shown in Figure 4 is used, the fuel electrode current collector 6 is made to have a shape in which the central part of the collector is swollen as compared to a conventional collector (for example, if the thickness of a conventional fuel electrode current collector 6 is about 0.75 mm, the maximum thickness of the central part is made to increase to the order of about 1.5 mm in the case of the present embodiment), and moreover, the peripheral part is made to be thinner as compared to the conventional type (for example, made to be of the order of 0.2 mm in relation to the thickness of 0.75 mm of the conventional type).

Additionally, as shown in Figure 6, respectively on both sides of the fuel cell stack 1, a manifold 15 for fuel for supplying fuel gas through connecting pipes 13 to fuel paths 11 in the respective separators 8 and a manifold 16 for oxidant for supplying oxidant gas through connecting pipes 14 to oxidant paths 12 in the respective separators 8 are arranged along the direction of the lamination of the electric power generation cells 5 in an extended manner.

According to the above described configuration of the fuel cell, the fuel gas discharged from the central part of the separators 8 is spread over the whole area of the fuel electrode layer 3 through the fuel electrode current collector 5 6 with a satisfactory distribution, and thus a satisfactory gas reaction can be carried out over the whole area of the electrode layer.

More specifically, as shown in Figure 8, in a conventional type having flat separators 8, the fuel electrode current 10 collectors 6 are also flat shaped, and in particular, the permeation rate of the fuel gas (the arrows in the figure) is fast in the neighborhood of the central part of each of the fuel electrode current collectors 6 (in other words, the retaining time of the gas in the current collector is short); 15 thus the electrode reaction in the neighborhood of the central part of the electrode layer is not completely carried out, and moreover, the situation is such that the gas is not sufficiently spread to the peripheral part, so that the nonuniformity of the electrode reaction is caused, and there 20 is a possibility such that most of the fuel gas not engaged in the reaction is vainly discharged outside the electric power generation cell. On the contrary, the use of the separators 8 shown in Figure 4 increases the volume of the fuel electrode current collectors 6 themselves, so that if the supplied amount 25 of the gas from the separators 8 is constant, the permeation rate of the gas is thereby made slower and the retaining time of the gas in the current collectors can be made longer. Consequently, the gas discharged from the central part of each

of the separators 8 can be made to permeate the wide area from the central part to the peripheral part of the fuel electrode current collector 6, and the fuel gas can thereby be supplied to the fuel electrode layer 3 in a uniformly distributed manner, so that a satisfactory gas reaction can be carried out over the whole area of the electrode layer.

Additionally, in each of the separators 8 of the present embodiment, the peripheral part is protruded expandably, and the thickness of the peripheral part of the fuel electrode current collector 6 thereby comes to be thinner than the thickness of the conventional type; therefore, particularly in the case of a sealless structure (a type in which the rim of the fuel electrode current collector has no gas seal), the linear velocity of the gas being discharged is increased in the peripheral part of the fuel electrode current collector, and the entraining of the air from the peripheral part is thereby prevented and the combustion reaction in the interior of the electric power generation cell can be inhibited, so that also in the peripheral part of the fuel electrode layer 3, there can be maintained a condition in which the fuel gas concentration is raised, and the improvement of the electric power generation performance can thereby be expected.

As described above, as for the present embodiment, description has been made on the shape of the surface, in contact with fuel electrode current collector 6, of the separator 8; the shape of the surface, in contact with the air electrode current collector 7, of the separator 8 can be made to have a similar shape. Additionally, the shape of the surface of

the separator 8 is not limited to the shape shown in Figure 4, and various shapes as shown in Figure 5a to Figure 5d are conceivable. In these figures, reference numeral 8a denotes a depression located in the central part or in the neighborhood thereof similarly to the case described above, reference numeral 8b denotes the peripheral part raised along the periphery of the depression 8a. To sum up, acceptable is a shape in which the volume of the current collector can be made larger, and thickness of the peripheral part can be made thin.

10 Additionally, as the porous structure of the current collectors 6 and 7, mesh, felt and the like can be used in addition to foam.

 Additionally, in the present embodiment, there is presented a solid oxide fuel cell in which a stabilized zirconia (YSZ) that is added with yttria is used for the electrolyte in the electric power generation cell; however, the present invention can be applied to other solid oxide fuel cells such as those solid oxide fuel cells in which a ceria based electrolyte and a gallate based electrolyte are used.

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Industrial Applicability

<Effect of the First Embodiment>

 As described above, according to the present invention set forth in claim 1 and claim 4, gas discharge openings are provided in the central part and the peripheral part of a separator, so that the gas can be sufficiently spread over the whole area of a current collector. Consequently, the electrode reaction can be carried out uniformly over the whole

area of the electrode, and thus an efficient electric power generation can be carried out in which the difference in electricity production between the central part and the peripheral part of the electric power generation cell is
5 eliminated.

Additionally, according to the present invention set forth in claim 2 and claim 5, the separators are made up by laminating a plurality of thin metal plates including at least the thin metal plates each provided with a first gas discharge
10 opening and second gas discharge openings and thin metal plates having a worked indented surface; consequently the separators themselves are made light in weight, and the number of lamination of a cell stack in a longitudinal type fuel cell module can thereby be increased, so that an electric power
15 generation of high electromotive force can be actualized. Additionally, the convexities and concavities form the gas flow path, and hence the introduced gas comes to be easily supplied to the whole area of the current collector, so that an efficient electric power generation can be actualized in
20 which the nonuniformity of the electrode reaction in the interior of the current collector is reduced.

Additionally, according to the present invention set forth in claim 3 and claim 6, the above described separator structure according to claim 1 and claim 2 is applied at least
25 to the separator part on the side of the fuel electrode current collector, so that the nonuniformity phenomenon of the electrode reaction in the interior of the fuel electrode current collector, which is conspicuous around the portions

where the supplied gas enters, can be effectively improved, and consequently an efficient electric power generation can be actualized in which the fuel utilization ratio is high.

<Effect of the Second Embodiment>

5 Additionally, according to the invention set forth in claim 7 and claim 12, indents are provided on the surface, in contact with one of the current collectors, of each of the separators, accordingly the dwell volume of the gas in the interior of the current collectors is increased, and hence
10 the retaining time of the gas is thereby made longer (the gas permeation rate is made slower). Consequently, the gas is slowly spread over a wide area through the current collector, a satisfactory gas reaction comes to be carried out over the whole area of the electrode layer. Accordingly, the fuel
15 utilization ratio and the air utilization ratio are increased, and the electricity generation performance is improved.

 Additionally, according to the invention set forth in claim 8 and claim 13, the peripheral part of the surface, in contact with the current collector, of the separator is
20 protruded expandably, accordingly the linear velocity of the gas being discharged is raised in the peripheral part, the entraining of the air from the peripheral part is prevented, and the combustion reaction in the interior of the electric power generation cell can be inhibited. Consequently, in the
25 peripheral part of the fuel electrode layer, there can be formed a condition in which the fuel gas concentration is raised, and the electric power generation performance is thereby improved.

Additionally, according to the invention set forth in claim 9 and claim 14, indents are provided on the surface, in contact with the current collector, of the separator, and the peripheral part of the separator is protruded in an expanded
5 manner; therefore, the effects set forth in claim 1 and claim 2 are obtained in which the permeation rate of the gas in the interior of the current collector is made slower and the electrode reaction is made satisfactory, moreover the linear velocity of the gas being discharged in the peripheral part
10 is made fast, and the entraining of the air from the peripheral part can be prevented.

Additionally, according to the invention set forth in claim 10 and claim 15, the above described surface shape of the separator is made to be formed at least on the surface
15 thereof in contact with the fuel electrode current collector, so that the phenomena of the incomplete reaction of the gas and the entraining of the air in the fuel electrode current collector are improved without failure, and hence the electric power generation performance is improved.

20 Additionally, according to the invention set forth in claim 11, the structure is such that the gases are supplied respectively from the central parts of the separators, respectively to the fuel electrode layer and the oxidant electrode layer, respectively through the fuel electrode
25 current collector and the oxidant electrode current collector; therefore, the gases slowly permeate over the wide areas from the central parts of the current collectors to the peripheral parts, and supplied to the electrode layers in a uniformly

distributed manner, and satisfactory electrode reactions come to be carried out over the whole areas of the electrode layers.